

Calculating the antimatter density in the Sun.

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Abstract

Every particle has an antiparticle, they have the same mass but opposite charge and these pairs particle-antiparticle annihilate each other producing photons¹. Using photons, neutrinos, protons and electrons data, the main goal of this project is to calculate the density of these antiparticles produced mainly by the proton proton chain inside the Sun.

Key words:

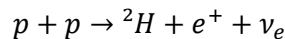
Antiparticles, neutrinos, proton proton chain.

Introduction

Analyzing the nuclear reactions inside the Sun, and studying theories from thermodynamics, special relativity, quantum mechanics and conservation laws we could calculate the density of positrons in the Sun. The positrons are mainly produced by the proton proton chain and they are the only antiparticle produced inside our nearest star. Using neutrinos flow data, photons density and the positron percentual production we could calculate the antiparticles density inside the Sun.

Results and Discussion

Produced in the transformation of Hydrogen to Helium, i.e., the proton proton chain (pp chain), the positron is the only antiparticle in the Sun, it is the associated antiparticle of the electron, so it has the same mass and opposite charge +1,602.10⁻¹⁹ C.² In the pp chain not only the positron is created but also an electronic neutrino and ²H:



As for each electronic neutrino produced there is a positron, we can use the neutrino flow detected on the Earth³ to find the positron production rate, that is 1,185.10⁵ cm⁻³.s⁻¹. Now, we need the positron lifetime to find the positron density inside the Sun, and for this we need the positron mean free path, its annihilation cross section and the positron-electron center of mass velocity.

We know the ²H velocity is almost zero, so we can say the neutrino and positron linear relativistic momentum are equal to 0,26 MeV/c, since the neutrino energy is 0,26 MeV⁴ and its mass is negligible. With this information, we can determine the positron velocity that is 0,45.c, which "c" is the light velocity. Considering the Sun is an ideal gas we can calculate the electron velocity with the equation

$$1,5kT = m_e \cdot c \cdot (\gamma - 1),$$

where T = 10⁷ K⁵ is the temperature inside the star, γ is the Lorentz factor, k is the Boltzmann constant and m_e the electron mass. Then, the electron velocity is 0,071.c, and the positron-electron center of mass velocity is 0,271.c². The center of mass velocity value (v_{cm}) is necessary to calculate the cross section given by

$$\sigma = \frac{4\pi}{c \cdot v_{cm}} \left(\frac{\hbar \cdot \alpha}{m_e} \right)^2 = 1,454 \cdot 10^{-22} \text{ cm}^2$$

where \hbar is the reduced Planck constant and α the Sommerfeld fine structure constant.

Now, using the cross section, we can find the positron mean free path inside the Sun, since it depends on the cross section by

$$l = \frac{1}{\sqrt{2}} \cdot \frac{V_{Sun}}{N \cdot \sigma} = 9,415 \cdot 10^{-3} \text{ cm}$$

With N = 10,3.10⁵⁶ being the number of electrons in the Sun, since 74% of the Sun mass is Hydrogen and 24% is Helium.

In the end, we can finally calculate the density of positrons inside the Sun using its production rate, and lifetime given by $\langle T \rangle = l/v(e^+)$. So, we have:

$$\rho_{CM} = 8,264 \times 10^{-8} \text{ cm}^{-3}$$
$$\rho = 7,955 \times 10^{-8} \text{ cm}^{-3}$$

In relation to the positron-electron center of mass and the Sun, respectively.

Conclusions

After studies and applications of a plenty of areas of physics and integral calculus we could determine that there are 80 million positrons per kilometer cubic inside our main star. It is possible to apply these results to find the neutrino flow and it is clear that this result is not impossible physically and this value is really close to the expected.

Acknowledgement

CNPq/PIBIC.

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³ Giunt C.; Kim W. *Fundamentals of Neutrino Physics and Astrophysics. Oxford University Press, 2007.*

⁴ Maciel W. J. *Introdução à Estrutura e Evolução Estelar. EdUsp, 1999.*

⁵ Broggi C. *Nuclear processes at Solar Energy. astro-ph/0308537*